



REVIEW ARTICLE

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Interdependence and contagion effects in agricultural commodities markets: A bibliometric analysis, implications, and insights for sustainable development

JEL Classification: C80; C58; Q17; F65; G14

Keywords: *bibliometric analysis; financial econometrics; agricultural commodities interdependence; contagion effect*

Abstract

Research background: The global interdependence of financial markets due to globalization has resulted in standardized trading conditions for agricultural commodities, reducing the advantages of portfolio diversification. Recent events between 2020 and 2023 underscore the growing importance of real-time information for investors to make informed decisions in this interconnected financial landscape.

Purpose of the article: This article aims to conduct a bibliometric review of the literature about market interdependence. We investigate the contagion effect on agricultural commodities and identify commodities and methods used in the most cited publications from 1997 to 2022.

Methods: A bibliometric analysis was developed, for this, the SCOPUS database was used, sorting with Rayyan, Excel, and finally, the Bibliometrix/R-project to extract bibliometric information from the database.

Findings & value added: The analysis highlights the prominent role of certain countries in contributing to scientific research on this topic, with China and the United States being leaders, collectively producing 24.57% of all publications in the examined periods. The research underscores the global concern for sustainable development, emphasizing the scientific growth linked to this topic and its intersection with energy sources. Unlike other bibliometric studies, this research consolidates relevant methodologies employed in analyzing interdependence and contagion effects in agricultural commodities over the past decades. Additionally, it identifies the most studied commodities in these works. As the world grapples with the challenges of market interdependence, particularly in the wake of recent events between 2020 and 2023, this study underscores the importance of real-time information for informed decision-making. The study suggests a shift towards cleaner and renewable energy sources in the coming years, anticipating increased investments in research and development.

Introduction

The economic system is a structure formed by multiple agents interacting with each other and presenting their collective properties, such as self-organization and self-regulation (Mantegna & Stanley, 1999). In this sense, we realize that one economic situation is associated with others and, in addition, is linked to social, environmental, scientific, and political varia-

bles, exercising a relationship of dependence or independence (Despard *et al.*, 2020). Technological development, the internet, and social media have accelerated the process of globalization and worldwide connectivity, enabling the real-time transmission of information. In turn, globalization has broken down international investment barriers, leading to increased interdependence (integration/correlation) among different countries and regions (Santana *et al.*, 2023), making socio-economic systems increasingly chaotic and susceptible to the transmission of crises, among other factors (Grass *et al.*, 2019). Understanding these relationships and monitoring their dynamics enables diversifying investment, structuring, and planning (Dias *et al.*, 2021).

The interdependence between markets or the indexes representing them is understood as a relationship, analysis of correlation, integration, or coupling between them (Bertero & Mayer, 1990; Guedes *et al.*, 2019; Pietrzak *et al.*, 2017; Reboredo *et al.*, 2014; Santana *et al.*, 2023; Silva *et al.*, 2015), where a change in behavior or interference in one system can disturb the dynamics of another system. Because of this, the contagion effect is understood as the effects' transmission of a financial or economic disruption (crash or volatility) from one sector, region, or market to another (Bashir *et al.*, 2019; Forbes & Rigobon, 2001; Santana *et al.*, 2023; Silva *et al.*, 2016). The interdependence among markets is a well-acknowledged characteristic during stable times. However, it becomes less favorable during crises due to the potential for risk transmission (the contagion effect) and market failure, which means that even in smaller sectors, market shocks can propagate, leading to a systemic and global crisis (Bashir *et al.*, 2019; Dias *et al.*, 2021; Guedes *et al.*, 2019; Reboredo *et al.*, 2014; Silva *et al.*, 2015).

Both globally and locally, society has constantly gone through various crises caused by the most diverse natures: energy and oil, 1980; Brazilian energy, 2001; the USA housing market, 2008; and recently we have the world economic recession, 2018; COVID-19, 2020; war between Russia and Ukraine, 2022 and war between Hamas and Israel, 2023 (Fiszeder & Małecka, 2022; Kramarova *et al.*, 2022; Liu *et al.*, 2021; Svabova *et al.*, 2021). These instabilities generate numerous social and environmental problems, such as inflation, hunger, unemployment, food insecurity, shortages, deforestation, inadequate land exploitation, and desertification (irrational use of natural resources), problems that we can associate with the pillars of sustainability and their interconnections (Despard *et al.*, 2020; Parra Paitan & Verborg, 2019; Santana *et al.*, 2023). Faced with the impact that the dy-

namics of interdependence or contagion have on understanding financial and economic markets and delineating investment strategies, investigations that contribute to and extend research related to this theme are considered of great relevance.

In the global scenario, agricultural commodities play a crucial role in sustainable equilibrium, given their allocation for human and animal food production, energy generation, pharmaceuticals, and other industrial inputs. Biofuels represent a strategy for the energy transition (shifting from more polluting to less polluting and renewable energy production). However, some studies express concerns regarding sustainability and the social, environmental, and economic balance (Herwartz & Saucedo, 2020; Pimentel *et al.*, 2009).

Notably, the agricultural sector gains prominence on the world stage as globalization introduces instability in a market player, potentially impacting food and energy production. The significance of this sector and the concern for its balance align with the Sustainable Development Goals proposed by the United Nations, including objectives such as Poverty Eradication, Zero Hunger and Sustainable Agriculture, Affordable and Clean Energy, Life Below Water and On Land, Action against Global Climate Change, among others.

Knowing what has already been produced by society is the first step towards continuity, development, adaptation, regulation, and application of scientific knowledge, especially when it comes to constantly changing phenomena subject to many interferences, such as economic relations. Faced with the questions raised, numerous methods can be combined to clarify a scientific investigation. Among them, we can mention bibliometrics. Bibliometric analysis represents one of the most consolidating and practical approaches to building the scientific memory of a given object of study.

In general terms, the bibliometric analysis represents an essential reference source for developing new research or even deepening scientific fields (Santana *et al.*, 2021; Vasconcelos *et al.*, 2020). The bibliometric techniques can be understood as a quantitative method to measure the interrelationships and impacts of publications within a given area of research using mathematical and statistical tools (Lajeunesse, 2016; Linnenluecke *et al.*, 2020; Santana *et al.*, 2021). This approach brings as a differential the possibility of describing the scientific production evolution in quali-quantitative terms. This review approach frequently addresses the scientific production

evolution by countries, authors, institutions or groups, and journals (Beckmann & Persson, 1998).

Although there are reviews in the literature that deal with themes associated with economic processes and their implications in general terms, productions that specifically deal with agricultural commodities in the light of interdependence or the effect of contagion are scarce in the literature. Some bibliometric studies associated with economics can be found, addressing the most cited journals in economics (Beckmann & Persson, 1998), field normalization and citation impact time in economics (Bornmann & Wohlrabe, 2019), the interference of COVID-19 on publications in economics (Bürge & Wohlrabe, 2022), green economy focused on economic and environmental factors (Rusydziana *et al.*, 2022) and the accounting literature since the financial crisis of 2008–2009 (Sampaio *et al.*, 2022).

In this sense, we provide in this paper not only a brief bibliometric review of the current scientific production in the agricultural commodities market, but also examine the literature that uses indexes of agricultural commodities to know what has been produced in the world literature on market interdependence in the context of agricultural commodities and to identify commodities and methods used in the publications most cited over the decades.

To achieve the article's aims, some questions were drawn that guided the construction of this research: What is the trend in the number of publications on interdependence or contagion effects in the agricultural commodities market? Which countries have published the most studies on interdependence or the contagion effect in the agricultural commodities market? What are the most cited publications on interdependence or contagion effects in the agricultural commodities market? Which authors have published the most about interdependence or contagion effects in the agricultural commodities market? Which journals have published the most studies on interdependence or the contagion effect in the agricultural commodities market? Which commodities are addressed in studies of interdependence or contagion effects on the agricultural market? What methods are applied in the studies to identify interdependence or contagion effects on the agricultural commodities market? What are the scientific perspectives on the analysis of interdependence and contagion effects in agricultural commodities concerning the sustainability discourse?

This study investigates a scientific gap, presenting the bibliographic framework regarding interdependence and contagion effects on agricultur-

al commodities. Unlike other bibliometric studies, we identify the applied methods and the commodities studied based on the most cited documents. Furthermore, we aim to recognize the direction this scientific field is taking in response to the demands of a more sustainable world. Therefore, it is not merely a retrospective view, but an analysis that will provide new guidelines for research.

The paper comprises five sections. Section 1 contains the introduction. A literature review is presented in Section 2. Section 3 details the materials and methods, while Sections 4 and 5 present and discuss the findings. Section 6 provides the conclusion.

Literature review

According to Mantegna and Stanley (1999), contemporary economic systems are inextricably linked due to their vast dependence on various elements. This interconnection creates a globally complex and interdependent economic system where events in one part of the world can have significant impacts on other regions (Bashir *et al.*, 2019; Guedes *et al.*, 2019; Silva *et al.*, 2016).

Advances in information technology and communications have shortened distances and accelerated the dissemination of information (Ajide & Dada, 2022; Haldar *et al.*, 2023). It creates an environment where economic decisions are influenced by real-time events anywhere in the world, increasing the complexity of economic systems. Recent articles, such as Fiszeder and Małecka (2022) and Pietrzak *et al.* (2017), have worked on these aspects.

Studies like those of Dias *et al.* (2021), Fiszeder and Małecka (2022), Pietrzak *et al.* (2017), and Santana *et al.* (2023) show that the integration of economies and the free flow of capital and investment have affected local and global economies. It reaffirms the interpretation that economic policies, financial crises, pandemics, and climate events in one country affect others, implying vulnerability and risk transmission (contagion effect).

Agricultural commodities are essential for sustainable global balance, destined for human and animal food production, energy production, medicines, and other industrial inputs. Some economic studies have addressed discussions about food security. Herwartz and Saucedo (2020) discuss volatility in the prices of food, oil, and agricultural inputs, showing the exist-

ence of volatility transmission and impacts on biofuel production. Pimentel *et al.* (2009) analyze the competition between food and biofuel production, exposing that the global population increase has intensified the demand for food and biofuels, aggravating malnutrition worldwide. Hamulczuk and Pawlak (2022) address the competitiveness of the global food industry and prove that the globalization of the economy positively impacts international competition.

It is crucial to develop resilient and sustainable management systems considering complexity and global dynamics to mitigate risks. It includes economic collaboration among various countries, investments in infrastructure, sustainable practices, and security policies (Beusch *et al.*, 2022; Ortiz-Martínez *et al.*, 2023). Effective management of these challenges requires global cooperation, sustainable practices, and the development of responsible strategies to reduce vulnerability.

Responsible and sustainable management, as advocated by the United Nations (2023), must "live today if we want a better tomorrow, meeting present needs without compromising the possibilities for future generations to meet their needs." According to them, balancing economic growth, environmental protection, and social inclusion is necessary. This concept and perspective can be identified in the sustainable development goals proposed in 2015: no poverty; zero hunger; good health and well-being; quality education; gender equality; clean water and sanitation; affordable and clean energy; decent work and economic growth; industry, innovation and infrastructure, reduced inequalities; sustainable cities and communities; responsible consumption and production; climate action; life below water, life on land; peace, justice, and strong institutions; partnerships for the goals.

The energy transition and sustainable development face various challenges related to energy production. Although biofuels are considered a cleaner alternative than fossil fuels, their production and use can have significant environmental and social impacts. Recent articles on the energy transition from reputable sources should be cited here.

Large-scale biofuel production can have significant social impacts, including the displacement of local communities, competition for resources, and a potential increase in food prices. It can affect food security and the well-being of vulnerable communities. Biofuel production from food crops creates competition between fuel and food production (Gasparatos *et al.*, 2022; Pimentel *et al.*, 2009; Tokarchuk *et al.*, 2022). It increases food prices

and puts more pressure on agricultural resources, especially during global food scarcity.

Addressing the challenges of producing cleaner energy requires a holistic approach involving the complexity demanded by globalization. The transition to sustainable biofuels must be carefully planned and implemented, considering environmental, social, and economic issues to ensure a cleaner and more resilient energy future.

In recent years, several studies have gathered and analyzed scientific production to identify elements that can positively influence the dynamics of global subsistence. These studies have used numerous methodologies, including bibliometrics, to answer their research questions.

Despite being a methodology recently driven by the development of applications and software, there are still few studies of economic nature. However, recently, studies such as those by Liu *et al.* (2021), Rusydiana *et al.* (2022), Bornmann and Wohlrabe (2019), Bürgi and Wohlrabe (2022), and Sampaio *et al.* (2022) have emerged, showing the increasing worldwide scientific production in various fields. Additionally, the scientific cooperation network has expanded and broken geographical boundaries, making relevant articles more likely to be cited. Despite the growth in the publication rate, bibliometric studies are still underexplored, especially considering specific topics in economic literature, such as independence and contagion effect. Another aspect that needs further exploration is bibliometric studies that combine with other research techniques and focus on an intra-documentary analysis, seeking to identify the main contributions of the investigated literature base.

Material and methods

This paper uses a bibliometric approach to analyze the literature on market interdependence. In addition, other topics, such as the contagion effect with agricultural indices associated with economic, social, environmental, and political perspectives at a given historical moment (1997–2022), were analyzed.

In our article, the bibliometric method was used as an approach to examining the state of science through the production of scientific literature (Galindo-Rueda & López-Bassols, 2022) to offer possibilities for quantitative and qualitative analysis of the countries' scientific production of

groups, institutions, authors, and journals (Mlambo-Thata, 2010; Vasconcelos *et al.*, 2020).

The investigation development can be identified from Table 1, which contains the guiding questions, analyses, and data that led to this investigation.

The methodological process to answer the research questions was developed in two stages. The first consists of building the database through identification, selection, and inclusion (see Figure 1). The SCOPUS database was used as a data source because it is comprehensive and multidisciplinary, with a more significant number of abstracts and citations (Elsevier, 2022). The second stage consists of processing and analyzing data for all articles or the subcategories indicated in Table 1, and its dynamics can be understood in Figure 1.

The first stage includes identification based on keywords, selection based on reading titles and abstracts, and the inclusion of texts for complete analysis. The second stage includes a data processing flowchart via Bibliometrix, analysis of whole texts, generation of results with an evaluation of answers, organization, structuring, and analysis.

First stage

The first stage began with a preliminary search in March 2022 in the SCOPUS database on order to identify the most commonly used terms and, thus, choose the keywords to compose the search, namely: (“agricultural commodities” OR “agriculture index” OR “livestock index” OR “agricultural index” OR “commodities agriculture” OR “commodities livestock”) AND (“Market Integration” OR “Market Interdependence” OR “Risk transmission” OR “contagion” OR “Overflow” OR “Spillover” OR “Tele-coupling”). After defining the search terms, 145 articles were identified using the filters: only articles, texts in English, Spanish, or Portuguese, and review articles were excluded because they did not answer the guiding questions.

The selection of documents was developed as follows: search in the SCOPUS database based on the search terms, export to the Rayyan application (<https://www.rayyan.ai/>) in which the screening of duplicates was carried out D , and reading the titles and abstracts. Subsequently, the search in the SCOPUS base was returned, excluding a duplicate, $D = 1$, and the incompatible texts identified from reading the titles and abstracts AT ($AT =$

17 these documents were excluded because they did not fit the objective of this study or did not answer the research questions). A total of 127 documents were admitted (see Table 2 and Table S1). In this stage, there was a concern about the accessibility of the complete texts, given the need to answer the questions “What commodities are addressed in studies of interdependence in the agricultural market?” and “What methods are applied in studies to identify interdependence in the agricultural commodities market?” and the associated sub-criteria are shown in Table 1. By consensus, the researchers decided to use a sample of 20% of the most cited articles per decade, i.e., an 80% percentile (see Tables 2, 3, 4 and 5).

Figure 1 details the search and selection stage of the scientific articles included in this study, adapted from the Prisma-Scr Flowchart (Prisma-Scr, 2022).

The construction of the database followed the process shown in Figure 1 with the identification of X documents, the exclusion of D duplicates, and AT texts that did not fit this investigation after reading titles and abstracts. The number of documents included in N can be expressed by the equation $N = X - D - AT$, the first stage's flowchart (see Figure 1), with the number of articles excluded and the reason for exclusion.

Second stage

Based on the questions in Table 1, bibliometric analysis was used to do the main analysis of the database. This entire step was initially developed with the support of Bibliometrix /R-project (Aria & Cuccurullo, 2017) and Excel/Microsoft because it has descriptive analytical functions that support this research. Furthermore, concerning bibliometric analysis, the Bibliometrix/R-project has been used by a growing number of publications (Lajeunesse, 2016; Rusydiana *et al.*, 2022) and has an easy-to-use free version that allows you to import data directly from SCOPUS, among other statistical and visualization advantages (Lajeunesse, 2016; Linnenluecke *et al.*, 2020).

With the Bibliometrix/R-project, tables and graphs were generated and analyzed to answer the research questions clearly and objectively. The development of this stage can be understood from Figure 1.

Figure 1 illustrates the development of the second stage: database processing with Bibliometrix/R-project, analysis of possible answers to research questions, clarity of results, extraction, and reorganization of infor-

mation, and finally, discussion of results. Regarding the 20% of the most cited articles per decade that supported questions 3.6 and 3.7 of the next section, they were carried out independently and blindly by two researchers, and they agreed upon the divergences.

The following section presents the results, analysis, and discussion. The arguments and reflections presented in this article are related to the research questions, objectives, results found, authors' expertise, and literature.

Results

In this section, we seek to present and describe the results according to the questions that guided this study. General information about data, keywords, authors, collaboration, and types of documents can be seen in Table 2.

What is the trend in the number of publications on interdependence or contagion effects in the agricultural commodities market?

Figure 2 shows the growth of the annual scientific production from 1997 to 2022, corresponding to the 127 articles that comprise this study's database. In black, we have the number of articles published annually, and in red, the accumulated production of articles. The first article dates from 1997, with another production in the next ten years. The number of publications has increased sharply since 2015 and in the last decade (with a production of 94 articles).

The results show that scientific production has been more significant in the last six years than in any other period. It is clear from the slope of the cumulative production curve, which shows a function with exponential characteristics and properties. From 2020 to 2021, there was a slight drop in the number of scientific papers published during this period, with 20 articles published in 2020 and 16 articles published in 2021.

Which countries have published the most studies on interdependence or the contagion effect in the agricultural commodities market?

The thematic map (see Figure 3) shows the countries that published the most on the topic discussed in this study. The blue color gradient indicates the regions that published articles, so the stronger tones indicate a more outstanding scientific production, while the lighter tones are minor. Gray-shaded regions represent negligible scientific production or have not been identified in this database. It is worth noting that Figure 3 shows the countries linked to the publications and that the production accounting is assigned to all countries involved in production.

The map also shows how little some regions of the world discuss the topic, opening space for scientific development in this area, especially in Russia, because, despite its economic influence and representativeness, it was impossible to identify linked scientific production.

What are the most cited publications on interdependence or contagion effects in the agricultural commodities market?

The most cited documents throughout the period studied, the top 10, are shown in Figure 2, which shows us a set of documents between 2011 and 2019, on the left and right, the number of citations. In addition, it is possible to identify in the exact figure the primary author and the journal that published the text. There is significant diversity in the authorship of the top 10, except for the fifth and eighth articles, which belong to the same author. The ten most cited articles are well distributed from 2011 to 2019, that is, one article in 2011, one in 2012, one in 2013, one in 2014, one in 2017, three in 2018, and two in 2019. Throughout this period, there was an average of 163.4 citations with a sample standard deviation of ± 79.6 .

Which authors have published the most about interdependence or contagion effects in the agricultural commodities market?

Figure 2, on the upper and left, shows the authors who published the most on interdependence or the effect of contagion in the agricultural commodities market (in descending order of those who contributed the most to the literary area under analysis), with an average productivity of 3.1 publications per author. From the results obtained in Figure 2, the au-

thors Hernandez and Bouri are the most productive. The productions of Hernandez and Bouri represent the authorship of four articles each, followed by the same number of publications by authors Ji, Kang, Nguyen, Roubaud, Shahzad, Umar and Yoon, who contributed three articles.

Which journals have published the most studies on interdependence or the contagion effect in the agricultural commodities market?

The journals that most contributed to the publication of articles that analyze the phenomenon of interdependence or contagion in the agricultural commodities market are identified in Figure 2, on the left and below.

In median terms, the ten journals shown in Figure 2 have an average publication of 4.6 articles over the analyzed period. It is possible to notice that most magazines identified as more productive focus on themes associated with economy, commerce, business, or finance, accumulating a volume of more than 73.9% of the articles published.

Which commodities are addressed in studies of interdependence or contagion effects on the agricultural market?

A sample with a minimum rate of 20% of the most cited articles per decade was defined among the authors, admitting 28 documents (see Table 3). In Table 4, the list of agricultural commodities with the most articles indexed by decade can be seen: 1997–2006 (the first decade), 2007–2016 (the second decade), and 2017–2022 (the third decade). Table 5 presents the frequency with which the commodity was studied in each period.

The results obtained for the first decade can be seen in Table 4. Rice and wheat were mentioned more frequently in the literature (two articles), followed by the study of cotton, corn, and soybeans (one article). In addition, it can be noted that in this decade, the article published in 2004 had a much higher number of citations than the article produced in 1997.

In the second decade, the study of the present theme gained relevance in analyzing the commodities corn and wheat, which integrated the sample of seven articles. Soybean was analyzed in three articles and sorghum in two studies. Barley, cotton, rice, and sugar, on the other hand, were part of only one article.

We can see in the third decade that all these commodities were present in at least one sample of the analyzed articles, standing out with their pres-

ence in 19 articles, except barley and sorghum, which were not studied in any article in the third decade. Prominently, corn was analyzed in 18 articles (95%), wheat in 16 (84%), soybeans in 15 (79%), cotton in 10 (53%), sugar in 9 (47%), coffee in 8 (42%), cocoa in 7 (37%), and rice in 6 (32%). Table 5 summarizes the frequency with which commodities were studied, emphasizing corn.

Overall, we analyzed 26 differentiated commodities in 28 articles. We can highlight the five commodities whose analysis in the context of the study of interdependence and the effect of contagion were more relevant, namely, corn (93%), wheat (89%), soybean (68%), cotton (43%) and sugar (36%). These five commodities were analyzed in articles during the three decades, and their analysis showed an increasing trend.

What methods are applied in the studies to identify interdependence or contagion effects on the agricultural commodities market?

Table 6 presents the methods used to identify interdependence and the effect of contagion in the most cited articles for decades. We emphasize that the methods referred in this study consist of procedures declared in the selected articles and can be understood as the most concrete steps. In restricted terms of general explanation and less abstract, a concept that can revolve around the most abstract notions of methodology, model, or technique was present.

In the first decade, the article by Tahir and Riaz (1997) applies the Ravallion methodology to study the integration between agricultural commodities selected for the sample. Later, in 2004, the article developed by Huang *et al.* (2004) applied the Engle-Granger cointegration methodology to analyze the integration of Chinese markets.

In the second decade under analysis, in 2011, the author Du *et al.* (2011) used a Bayesian methodology (SVMJ model) to study the contagion effect. Reboredo (2012) studied co-movements using various models of copulas. In the following year, Nazlioglu *et al.* (2013) examined the volatility transmission between the prices of selected agricultural commodities, applying the causality test in the variance test and impulse response functions to daily data (CIV-IRF). These are the most cited articles of the second decade.

In 2014, Beckmann and Czudaj (2014) applied for the GARCH-in-mean VAR model. In the same year, Baquedano and Liefert (2014) applied an error correction model (SEECM) to identify cointegration. Finally, Mensi *et*

al. (2014) and Hernandez *et al.* (2014) used the VAR-BEKK-DCC-GARCH models to analyze possible market links.

In the third decade, in the year 2017, the authors Arnade *et al.* (2017) used the VAR-ECM method to analyze the economic phenomenon of integration. In turn, Kang *et al.* (2017) applied the DECO-GARCH model to analyzing the contagion effect.

Zafeiriou *et al.* (2018) examines the relationships of crude oil–corn–soybean prices with ARDL cointegration approach. Saghaian *et al.* (2018), who, like the authors Mensi *et al.* (2014) used the BEKK-MGARCH method. Shahzad *et al.* (2018) and Ji *et al.* (2018) used the same method, namely Co-VAR, to study the contagion effect. Luo and Ji, (2018) and Ji *et al.* (2019) analyze the connectivity characteristics of variable volatility combined the multivariate heteroscedastic autoregressive model (HAR) with the DCC-GARCH model. Hernandez *et al.* (2019), chose to use the CQ approach to examine the effect of extreme quantiles of returns between commodities.

Bonato (2019) relied on a volatility model, the Beta GARCH model performed by Hansen *et al.* (2014). Barbaglia *et al.* (2020) and Dahl *et al.* (2020) in that same year, studied the contagion effect using the vector autoregressive model (VAR) and the EGARCH, respectively. Su *et al.* (2019) chose to use a bivariate autoregressive vector to analyze dynamic causal relationships. Yip *et al.* (2020) employed the fractionally integrated VAR (FIVAR) model to capture the dynamical patterns of volatility spillover effects.

More recently, Umar *et al.* (2021) published paper applying different techniques, Granger test methods with index created by Diebold and Yilmaz (2009) and TVP-VAR (time-varying parameter with vector autoregressive), this last method is the same one applied by Bouri *et al.* (2021). In the same year, he published an article with the objective for analyzing the overflow between agricultural commodities and oil using the Wavelet Coherence method with an index by Diebold and Yilmaz (2009). Later, in 2022, Tiwari *et al.* (2022) applied the Quantile Vector autoregressive to develop his research.

What are the scientific perspectives on the analysis of interdependence and contagion effects in agricultural commodities concerning the sustainability discourse?

The analysis of interdependence and contagion effects in agricultural commodities concerning sustainability is a complex field that involves various scientific perspectives. The integration of these perspectives can pro-

vide an understanding of the collective dynamics of markets, thereby contributing to the formulation of more sustainable policies and practices.

The data analysis suggests a correlation between the rise number of publications, the countries with the highest publication rates, the most cited articles and authors, the journals with the highest publication rates, and the most investigated commodities. Upon examining these results, it becomes evident that there is an increasing worldwide interest in sustainable development and achieving a balance between our society's social, economic, and environmental aspects.

This scientific scenario demonstrates how agricultural production is crucial in global food supply and biofuel production. The dualism and competition for inputs between these markets pose a challenge to be overcome. The increasing demand for food and biofuels often results in conflicts, leading to agricultural intensification, extensive land use, and environmental pressures. The competition for resources, such as land and water, exacerbates these issues, highlighting the need for sustainable approaches to reconcile food and biofuel production, minimizing negative impacts on the environment, economy, and society.

Discussion

We discuss below the descriptive and analytical aspects visualized in the results achieved. According to an analysis of the publication's development (see Figure 2) 94 articles (or 74% of the total number of publications) were released between 2017 and 2022.

In the first decade, there was an average production of 0.2 articles. In the second decade, there was an average production of 3.1 articles per year, while in the third decade, the average production of articles was 15.7.

Even though there was a decline in scientific output from 2020 to 2021 (likely due to the global crisis brought on by COVID-19), it can be seen from the evolution of the number of publications, particularly in recent years, that there is a trend of growth of publications about the theme by 2022. It is like the growth trends seen before the pandemic.

The distribution of scientific production is concentrated in a few countries, mainly: China, the USA, India, France, Australia, Italy, Brazil, Greece, the UK, and Germany (see Figure 3). The first three are also the countries with the largest population in the world, and most have significant eco-

conomic representation in the world. They are part of the G20, and China, the USA, France, and the UK participate in the Permanent Council of the UN (United Nations Organization). The correspondence between scientific production and development is evident in the representativeness of the countries that have published the most and their expression in the economic, political, and social world (Despard *et al.*, 2020; Guedes *et al.*, 2019).

In the articles that make up this database, the three most cited documents are in the journal *Energy Economics* (<https://www.sciencedirect.com/journal/energy-economics>), and 70% of the most cited articles are concentrated there. In addition, the three most cited articles have an average of 272 citations, with the first one dating from 2017, the second from 2011, and the third from 2013. While the ten most-cited articles have an average of 163 citations per document (see Figure 2).

There is no clear trend toward older publications receiving more citations, as shown by the distribution of the most frequently cited articles by date.

Still, among the most cited documents, we have the authors who published the most (see Figure 2),

Authors Hernandez and Bouri despite having the largest output (see Figure 2), have no documents that rank among the most frequently cited documents examined. Figure 2 demonstrates that if we consider the 3 articles published per year from 1997 to 2022, the average production per author is low. According to Figure 2, the most productive authors are associated with the most diverse nations.

Figure 2 shows that *Energy Economics* has a greater number of publications on the object of study, indicating a particular scientific relevance in studies that address agricultural commodities and energy. It is believed that the concentration of these studies in journals with an economic bias is somehow associated with the production of biofuels (Pimentel *et al.*, 2009; Quintino *et al.*, 2021; Rosales-Calderon & Arantes, 2019; Rusydiana *et al.*, 2022).

A sample of 20% of the articles that received the highest citations throughout the period was gathered to identify the agricultural commodities and the research methodologies employed, as was described in the preceding section (see Table 3).

Table 4 lists the commodities discussed in the most frequently cited studies for each period under analysis. As a result, we can see that the

commodities needed to produce food for humans and animals are commonly used in the articles under study.

Furthermore, the association between energy and agricultural commodities in the most widely read and cited publications suggests concern for both agricultural production and energy-related issues (biofuels). In particular, corn, wheat, and soybeans because they are globally popular foods and the source of biofuels.

Table 6 also summarizes the most frequently mentioned studies and research techniques for each period.

In general, the non-co-occurrence of the analysis methods over the years shows that no universally accepted method contemplates the absolute universality of the phenomenon and that new methods, divergent or complementary, may arise with the development of research in this area.

The discussion of the results obtained in this study presents a direction for research involving agricultural commodities (food) and energy sources. In this sense, there is a global concern about more sustainable economic policies, efficiency, and rational use of environmental resources, that is, equitably balancing social, economic and environmental needs, given that the planet is increasingly interconnected and the instability of one region is spreading to others faster and faster (Mantegna & Stanley, 1999; Parra Paitan & Verburg, 2019).

As we face the ever-growing demand for a more balanced structure among society, the environment, and the economy, we must focus on interdependence, contagion effect, and sustainability. It is particularly crucial when it comes to the energy transition process. Investing in scientific solid production and research can pave the way towards a more equitable and sustainable future. Let us prioritize this vital work and create a better world for ourselves, our children, and future generations. Balcerzak *et al.* (2023) emphasize that sustainability is related to overcoming the challenges of the energy transition and obtaining renewable sources and socio-economic balance. In general, it is anticipated that there will be increased investments in research promoting cleaner energy production alongside socio-economic stability in the coming years or decades, as evidenced by studies discussing waste utilization (Tokarchuk *et al.*, 2022).

Conclusions

This study assumes that the world is a complex system that has become increasingly globalized, reducing borders and bringing cultures, economies, and policies closer together. In the same way, through the perspective of sustainability, we relate environmental, social, and economic issues. In this paper, we identify the main patterns of literature production associated with market interdependence, the effect of contagion using agricultural commodity indices, and the commodities and methods used in the most cited publications over the decades. Intending to carry out a bibliometric mapping, we outlined some questions (see Table 1) that were answered in the previous sections.

We conclude from the results and discussions that the scientific production concerning the theme discussed in this article has grown faster and faster in recent years, mainly since the financial crisis of 2008, without concentration among the most cited and productive authors. However, there is a direction for discussion between agricultural commodities and energy. In addition, the most-cited documents are published in magazines focused on economics, finance, or business.

Because of their large populations and high energy consumption, the world's two most significant powers, China and the USA, are the greatest producers of knowledge on the subject, with 24.57% of the publications of articles on the world from 1997 to 2022. Supplies like corn, wheat, soy, cotton, and sugar were the most studied products over the analyzed period (corn is highlighted as being present in 93% of the articles).

The numerous approaches taken to study the interdependence and effect of contagion on the financial markets, particularly in the commodities markets, must also be emphasized. In this field we also identify opportunities for new or improved techniques development.

When used to investigate financial phenomena like interdependence and the contagion effect, a variety of methods and approaches can arise and complement one another. As a result, it is impossible to identify a method or strategy that is generally accepted.

The mapping of scientific production identified in this study indicates a trend of investment and growth in the clean energy sector. It is motivated by the global energy transition process involving social, economic, and environmental interaction.

Among its main contributions, this article offers an overview of the evolution of the interdependence analysis or effect of contagion in the context of agricultural commodities, indicating directions and gaps. In addition, this study will allow for future thoughts associated with research questions, results, and considerations achieved with this methodological approach. These results still can be explored in dialogue with what has already been produced by humanity, bringing new scientific elements and other information that help understand these and, eventually, other phenomena.

However, subsequent research is expected to continue the issues raised here and use the information in this article. We also highlight that analyzing social networks, words, clusters, and other metrics can imply new investigations concerning our object of study.

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Annex

Table 1. This table describes the link between research questions, analysis (statistical procedure) and data. In the first column, we have the questions, in the second column we have the type of results/analysis and in the third column the data that were used

Question	Analysis	Data
What is the trend in the number of publications on interdependence or contagion effects in the agricultural commodities market?	Descriptive Statistics / Frequency Distribution (Publications x Year of publication)	All articles
Which countries have published the most studies on interdependence or the contagion effect in the agricultural commodities market?	Descriptive Statistics/ Mapping (Country linked to publication x Number of publications)	All articles
What are the most cited publications on interdependence or contagion effects in the agricultural commodities market?	Descriptive Statistics / Frequency Distribution (Authors x Number of publications)	All articles / 10 more published
Which authors have published the most about interdependence or contagion effects in the agricultural commodities market?	Descriptive Statistics / Frequency Distribution (Authors x Number of publications)	All articles / 10 more cited
Which journals have published the most studies on interdependence or the contagion effect in the agricultural commodities market?	Descriptive Statistics / Frequency Distribution (Magazines x Number of publications)	All articles / 10 more published
Which commodities are addressed in studies of interdependence or contagion effects on the agricultural market?	Descriptive Statistics / Frequency Distribution (Documents x Commodities)	20% of the most cited articles by decade
What methods are applied in the studies to identify interdependence or contagion effects on the agricultural commodities market?	Descriptive Statistics / Frequency Distribution (Documents x Methods)	All articles / 20% of the most cited articles by decade
What are the scientific perspectives on the analysis of interdependence and contagion effects in agricultural commodities concerning the sustainability discourse?	Inferential analysis from the perspective of sustainability.	Set of the results.

Table 2. General description of the database. The description is divided into Main information about data, Document contents, Authors, Authors collaboration and Document types

Description	Results
Main about data	-
Timespan	1997:2022
Sources (Journals, Books, etc)	79
Documents	127
Annual Growth Rate %	13.16
Document Average Age	4.87
Average citations per doc	26.54
References	5512
Document contents	-
Keywords Plus (ID)	420
Author's Keywords (DE)	384
Authors	-
Authors	324
Authors of single-authored docs	5
Authors collaboration	-
Single-authored docs	5
Co-Authors per Doc	2.92
International co-authorships %	37.8
Document Types	-
Article	127

Source: Own elaboration using package Bibliometrix /R-project.

Table 3. Describes the number of articles accepted in the sample. The first column presents the subdivision by decade, the second column the number of articles for each period, and the third column the admitted sample

	Number of articles per decade	Sample admitted
First decade	2	2
Second decade	31	7
Third decade	94	19

Table 4. Agricultural commodities identified in the studies. The first column presents the subdivisions by decade, the second is the study's identification, the third is the number of citations, and the fourth presents the commodities analyzed in that document

	Study	Number of citations	Commodities
First decade	Tahir and Riaz, 1997, Pak Dev Rev	3	Wheat, Cotton, Rice
	Huang <i>et al.</i> , 2004, World Bank Econ Rev	55	Corn, Soybean, Rice, Wheat
Second decade	Hernandez <i>et al.</i> , 2014, Eur Rev Agric Econ	57	Corn, Wheat, Soybean
	Beckmann and Czudaj, 2014, Econ Model	57	Cotton, Wheat, Corn
	Baquedano and Liefert, 2014, Food Policy	62	Wheat, Rice, Corn, Sorghum
	Mensi <i>et al.</i> , 2014, Energy Econ	124	Barley, Corn, Sorghum, Wheat
	Reboredo, 2012, Energy Policy	140	Corn, Soybean, Wheat
	Nazlioglu <i>et al.</i> , 2013, Energy Econ	255	Wheat, Corn, Soybean, Sugar
	Du <i>et al.</i> , 2011, Energy Econ	259	Corn, Wheat
Third decade	Tiwari <i>et al.</i> , 2022, Energy Econ	24	Corn, Wheat, Soybean, Coffee, Cotton, Sugar
	Umar <i>et al.</i> , 2021, Plos One	27	Soybean, Wheat, Cocoa, Coffee, Cotton, Feeder cattle, Lean hogs, Live cattle, Livestock Sugar
	Amade <i>et al.</i> , 2017, J Commod Markets	28	Beef, Corn, Cotton, Pork, Wheat, Soybean, Soybean Meal, Chicken, Rice
	Hernandez <i>et al.</i> , 2019, Resour Policy	28	Wheat, Corn, Rice
	Saghaian <i>et al.</i> , 2018, J Agric Resour Econ	30	Corn
	Bonato, 2019, J Int Financ Mark Inst Money	31	Corn, Soybeans, Wheat, Soybean oil, Coffee, Cotton, Sugar, Cocoa
	Zafeiriou <i>et al.</i> , 2018, Sustainability	33	Soybean, corn
	Barbaglia <i>et al.</i> , 2020, Energy Econ	37	Corn, Wheat, Soybean, Sugar, Cotton, Coffee
	Bouri <i>et al.</i> , 2021, Int Rev Econ Financ	41	Cocoa, Coffee, Corn, Cotton, Orange juice, Soybean, Soybean meal, Sugar, Wheat
	Yip <i>et al.</i> , 2020, Int Rev Financ Anal	46	Corn, Wheat, soybean
	Dahl <i>et al.</i> , 2020, J Commod Markets	55	Corn, Wheat, Soybean, Soybean meal, Soybean oil, Canola, Cocoa, Sugar, Cotton, Coffee
	Shahzad <i>et al.</i> , 2018, Energy Policy	69	Wheat, Corn, Soybean, Rice
	Ji <i>et al.</i> , 2019, Energy Econ	111	Live cattle, Cocoa, Coffee, Corn, Cotton, Lean hogs, Orange juice, Soybean, Wheat, Sugar
	Luo and Ji, 2018, Energy Econ	115	Soybean, Corn, Cotton, Wheat, Palm
Ji <i>et al.</i> , 2018, Energy Econ	150	Corn, Rice, Soybean, Wheat	
Kang <i>et al.</i> , 2017, Energy Econ	275	Corn, Wheat, Rice	

Table 5. Number of times the commodity was studied in each decade and the total period. In the first column, the commodity is presented; in the second, third, and fourth columns, the number of articles per decade that studied the commodity; and in the last column, the number of studies in which the commodity was studied throughout the period

Commodities	Number of articles			
	1st decade 1997:2006	2nd decade 2007:2016	3rd decade 2017:2022	All period
Barley	-	1	-	1
Beef	-	-	1	1
Canola	-	-	2	2
Chicken	-	-	1	1
Cocoa	-	-	7	7
Coffee	-	-	8	8
Corn	1	7	18	26
Cotton	1	1	10	12
Feeder cattle	-	-	2	2
Lumber	-	-	1	1
Lean hogs	-	-	3	3
Live cattle	-	-	3	3
Livestock	-	-	1	1
Oats	-	-	2	2
Orange juice	-	-	3	3
Palm	-	-	1	1
Pork	-	-	1	1
Rice	2	1	6	9
Rubber	-	-	1	1
Sorghum	-	2	-	2
Soybean	1	3	15	19
Soybean meal	-	-	3	3
Soybean oil	-	-	2	2
Sugar	-	1	9	10
Wheat	2	7	16	25
Tea	-	-	1	1

Table 6. Methods identified in the studies. The first column presents the subdivisions by decade, the second the identification of the study, the third the number of citations, and the fourth the method presented by the authors of the document

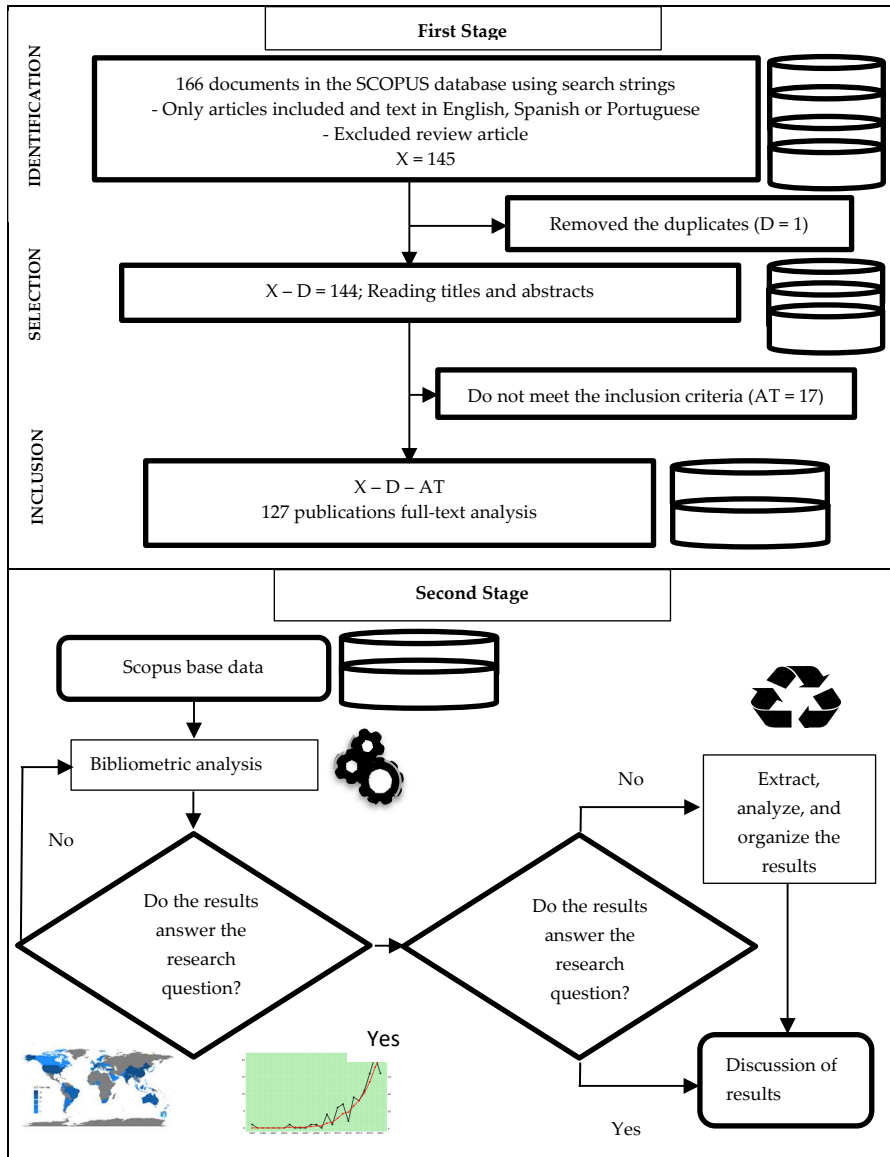
	Study	Number of citations	Methods*
First decade	Tahir and Riaz, 1997, Pak Dev Rev	3	Ravallion model
	Huang <i>et al.</i> , 2004, World Bank Econ Rev	55	Cointegration Engle-Granger

Table 6. Continued

	Study	Number of citations	Methods*
Second decade	Hernandez <i>et al.</i> , 2014, Eur Rev Agric Econ	57	VAR-BEKK-DCC-MGARCH
	Beckmann and Czudaj, 2014, Econ Model	57	VAR-GARCH
	Baquedano and Liefert, 2014, Food Policy	62	SEECM
	Mensi <i>et al.</i> , 2014, Energy Econ	124	VAR-BEKK-DCC-MGARCH
	Reboredo, 2012, Energy Policy	140	Copula models
	Nazlioglu <i>et al.</i> , 2013, Energy Econ	255	CIV - IRF
	Du <i>et al.</i> , 2011, Energy Econ	259	SVMJ
Third decade	Tiwari <i>et al.</i> , 2022, Energy Econ	24	Quantile VAR
	Umar <i>et al.</i> , 2021, Plos One	27	Granger causality tests and index of Diebold and Yilmaz
	Arnade <i>et al.</i> , 2017, J Commod Markets	28	VAR-ECM
	Hernandez <i>et al.</i> , 2019, Resour Policy	28	CQ Approach
	Saghaian <i>et al.</i> , 2018, J Agric Resour Econ	30	BEKK-MGARCH
	Bonato, 2019, J Int Financ Mark Inst Money	31	Beta-GARCH
	Zafeiriou <i>et al.</i> , 2018, Sustainability	33	ARDL
	Barbaglia <i>et al.</i> , 2020, Energy Econ	37	VAR
	Bouri <i>et al.</i> , 2021, Int Rev Econ Financ	41	TVP-VAR
	Yip <i>et al.</i> , 2020, Int Rev Financ Anal	46	FIVAR
	Dahl <i>et al.</i> , 2020, J Commod Markets	55	EGARCH
	Shahzad <i>et al.</i> , 2018, Energy Policy	69	GARCH-Copulas
	Ji <i>et al.</i> , 2019, Energy Econ	111	Entropy Transfer
	Luo and Ji, 2018, Energy Econ	115	HAR and DCC-GARCH
	Ji <i>et al.</i> , 2018, Energy Econ	150	CoVaR-copulas
	Kang <i>et al.</i> , 2017, Energy Econ	275	DECO-GARCH

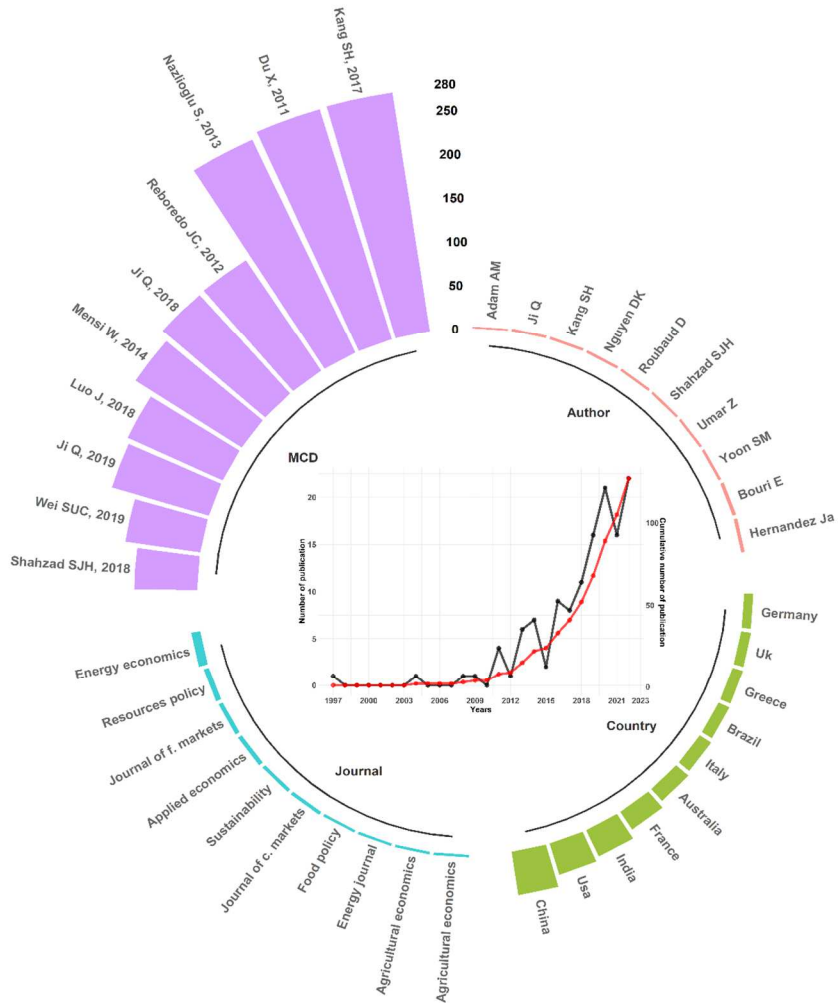
Note: * GARCH: Generalized autoregressive conditional heteroscedasticity; VAR: Vector autoregressive; MGARCH: Multivariate GARCH; EGARCH: Exponential GARCH; BEKK-MGARCH (Baba Engle Kraft Kroner MGARCH): stochastic volatility models with jumps; BFGS: Broyden Fletcher Goldfar Shanno; ECM: Error correction model; CIV: Causality in variance; IRF: Impulse response functions; SEECM: Single equation error correction model; TVP: time-varying parameter; DCC: Dynamic conditional correlation; HAR: Autoregressive heterogeneous; ARDL: Autoregressive Distributed Lag; FIVAR: Fractionally integrated autoregressive template vector multivariate; DECO: Dynamic de Equicorrelation.

Figure 1. The scheme represents the database and activities employed in the study stages



Source: Own elaboration using the Canvas app. Note: The first stage includes identification based on keywords, selection based on reading titles and abstracts, and the inclusion of texts for complete analysis. The second stage includes a data processing flowchart via Bibliometrix, analysis of whole texts, generation of results with an evaluation of answers, organization, structuring, and analysis.

Figure 2. General statistics associated with the top 10 for the most cited documents (MCD), production sources (Journal), most productive authors (Author) and countries and annual publication growth (black curve, left y-axis) compared to cumulative annual growth (red curve, right y-axis) rate of all manuscripts indexed in the Scopus database by year (1997–2022)



Source: Own elaboration using package ggplot2 /R-project.

Figure 3. Map of scientific production associated with countries. More intense tones indicate greater scientific production. Source: Elaboration of the authors

Country Scientific Production



Source: Own elaboration using package Bibliometrix /R-project.